

REMARKS

In view of the above amendments and following remarks, reconsideration and further examination are requested.

In section 4 on page 2 of the Office Action, the Examiner objected to the disclosure because it is unclear as to what "FT-IR" stands for. In response to this objection, it is hereby stated that "FT-IR" stands for Fourier Transform Infrared Spectroscopy. In support of this, provided herewith are copies of pages 636-639 of a text entitled **ENCYCLOPEDIA OF CHEMICAL TECHNOLOGY**. Please see from the bottom of page 636 through page 637.

In response to section 5 on page 2 of the Office Action, the specification and abstract have been reviewed and revised to make editorial changes thereto and generally improve the form thereof, and a substitute specification and abstract are provided. No new matter has been added by the substitute specification and abstract. Also, enclosed is a "marked-up" copy of the original specification and abstract to show changes that have been incorporated into the substitute specification and abstract. The attached pages are captioned **"Version With Markings To Show Changes Made."**

By the current Amendment, claims 1-8 have been cancelled and claims 9-29 have been added. New claims 9-29 have been drafted taking into account the 35 U.S.C. 112, second paragraph, rejection as expressed in section 7 on page 3 of the Office Action, and claims 9-29 are believed to be free of each of the 35 U.S.C. 112, second paragraph, issues raised by the Examiner.

The instant invention pertains to an apparatus for treating a waste gas containing fluorine-containing compounds. With reference to Figure 1, in accordance with a first aspect of the invention the apparatus comprises a solids treating device 1 for separating solids from a waste gas, an addition device for adding a decomposition assist gas to the waste gas leaving the solids treating device, a thermal decomposition device 3 for thermally decomposing the waste gas to which the decomposition assist gas has been added, and an acidic gas treating device 5 for removing acidic gases from the thermally

decomposed waste gas. The thermal decomposition device 3 is packed with γ - alumina heated at 500°C to 1000°C. Claim 9 is believed to be representative of this aspect of the invention.

In accordance with a second aspect of the invention, the apparatus further comprises an air ejector 7 for controlling pressure in each of the solids treating device 1, the thermal decomposition device 3 and the acidic gas treating device 5. When a waste gas passes through the apparatus, a pressure for passing the gas is required to be elevated because of each of the devices 1, 3 and 5 contains therein some structure which obstructs flow of the gas. However, if pressure in the apparatus is inappropriately elevated, a waste gas may not flow through the apparatus or may flow away from the apparatus. In order to prevent such problems, gas flow is adjusted by the air ejector 7 so as to appropriately control pressure in the apparatus. Claim 29 is believed to be representative of this aspect of the invention.

In accordance with a third aspect of the invention, the apparatus further comprises an FT-IR analyzer for monitoring treated gas exiting from the acidic gas treating device 5 so as to control emission density of the treated gas. Specifically, the analyzer is installed for monitoring composition of the treated gas so as to determine degree of deterioration of the γ -alumina during a decomposition reaction. For this purpose, the FT-IR analyzer is the best analyzer to be used in the apparatus of the present invention. Claims 24-27 are believed to be representative of this aspect of the invention.

In accordance with a fourth aspect of the invention, the apparatus further comprises a bypass valve 8 such that waste gas can be directly conveyed to a discharge line without being first conveyed to the solids treating device 1. Accordingly, even if a problem arises in the apparatus, a fluorine-containing waste gas can be discharged from a semiconductor fabrication plant by actuating the bypass valve 8. Claim 28 is believed to be representative of this aspect of the invention.

The invention in accordance with the first, second, third and fourth aspects of the invention are not believed to be disclosed or suggested by EP '388 or EP '648, either taken alone or in combination.

The Examiner rejected claims 5-8 under 35 U.S.C. 103(a) as being unpatentable over EP '388 in view of EP '648. This rejection is respectfully traversed and the references relied upon by the Examiner are not applicable with regard to the newly added claims for the following reasons.

With regard to former claim 5, which generally corresponds to new claim 9, the Examiner took the position that EP '388 discloses the basic apparatus as claimed except for the specific type of alumina in the thermal decomposition unit 76. The Examiner thus relied upon EP '648 for a teaching that one having ordinary skill in the art would have found it obvious to substitute an γ -alumina for the alumina 11 of the EP '388. This position taken by the Examiner is respectfully traversed as follows.

While EP '648 does disclose γ -alumina, this γ -alumina is a raw material from which a catalyst is manufactured, but EP '648 does not express that the catalyst itself is of γ -alumina. Please see page 4, lines 6-8 of EP '648. Indeed, none of the twenty catalysts disclosed on pages 6-9 of EP '648 express that the catalyst is γ -alumina. Accordingly, because EP '388 does not disclose the catalyst 11 thereof to be γ -alumina, and because EP '648 also does not disclose an γ -alumina catalyst, any combination of these references would not result in the invention as recited in former claim 5 and new claim 9. Accordingly, claim 9 is not obvious over a combination of EP '388 and EP '648. Thus, claims 9-29 are allowable over a combination of these references.

With regard to former claim 7 and new claim 29, even though EP '388 discloses a device 59 for adjusting pressure of the apparatus, device 59 is a blower and not an "air ejector" as recited in these claims. Having the device for controlling pressure in the apparatus be an air ejector instead of a blower is significant in that an air ejector is resistant to erosion caused by exposure to a fluorine-containing mist. Additionally, with use of an air ejector it is possible to easily and flexibly control pressure in the apparatus, as

compared to using a blower. EP '648 also does not disclose an air ejector, and accordingly, because neither EP '388 nor EP '648 disclose or suggest an air ejector, claim 29 is patentable in its own right over a combination of these references.

With regard to former claim 7 and new claims 25 and 26, while EP '388 does disclose a device for monitoring or controlling treated gas, this device is a gas chromatography device and is not an "FT-IR" analyzer. An, FT-IR analyzer is significant because it is useful for measuring multiple components at a single time and can easily be operated to conduct real-time measurements. Accordingly, an FT-IR analyzer is more suitable for monitoring the deactivation degree of a catalyst used in a treating apparatus than is a gas chromatography device as disclosed in EP '388. EP '648 also does not disclose or suggest an FT-IR analyzer, and accordingly, claims 25 and 26 are each patentable in its own right over a combination of these references.

Finally, new claim 28 recites a bypass including a bypass valve such that waste gas can be conveyed to a discharge line without entering the solids treating device. Such a bypass is not taught or suggested by either of EP '648 or EP '388, and accordingly, claim 28 is patentable in its own right over a combination of these references.

In view of the above amendments and remarks, it is respectfully submitted that the present application is in condition for allowance and an early Notice of Allowance is earnestly solicited.

If after reviewing this Amendment, the Examiner believes that any issues remain which must be resolved before the application can be passed to issue, the Examiner is invited to contact the Applicants' undersigned representative by telephone to resolve such issues.

Respectfully submitted,

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Version with Markings to
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- 1 -

METHOD AND APPARATUS FOR TREATING A WASTE GAS
CONTAINING FLUORINE-CONTAINING COMPOUNDS

BACKGROUND OF THE INVENTION

This invention relates to ~~the~~ treatment of a waste
5 gas containing fluorine-containing compounds. More
particularly, it relates to a method and an apparatus for
efficient treatment of emissions from semiconductor
fabrication plants, particularly from ~~the~~ steps of dry
cleaning ^{an} the inner surface of a fabrication apparatus
10 and etching various kinds of deposited films with
perfluorocarbons (PFCs) and halogenated hydrocarbons such
as C_2F_6 , C_3F_8 , CHF_3 , SF_6 and NF_3 . ^{The} said waste gases ^{contain} ~~containing~~
not only PFCs but also oxidizing gases such as F_2 , Cl_2 and
 Br_2 , acidic gases such as HF , HCl , HBr , SiF_4 , $SiCl_4$, $SiBr_4$,
15 and COF_2 , as well as CO .

Semiconductor fabrication plants use many kinds of
harmful gases that can potentially pollute the environment.
PFCs contained in waste gases that typically result from
the etching and CVD steps are suspected of causing global
20 ^{warming} ~~warning~~, and it is urgently needed to establish an effective
system for their removal.

Various breaking and recovery techniques have
heretofore been proposed for PFC removal. Catalytic
thermal decomposition is one of the breaking techniques and
25 uses versatile compounds such as Pt catalyst, zeolite-based
catalysts, activated charcoal, activated alumina, alkali
metals, alkaline earth metals and metal oxides. However,
none of these catalytic compounds have proved completely
satisfactory.

30 ~~The~~ ^a Waste gases discharged from the semiconductor
fabrication process contain not only PFCs, but also
oxidizing gases such as F_2 , Cl_2 and Br_2 , acidic gases such
as HF , HCl , HBr , SiF_4 , $SiCl_4$, $SiBr_4$ and COF_2 , as well as CO ;
however, no method has yet been established that can
35 realize a thorough and effective treatment of these harmful
gases.

If one wants to treat oxidizing gases such as F_2 , Cl_2 ,
and Br_2 by a wet method, thorough treatment cannot be

achieved by ~~the sole~~^{alone} use of water. If alkali agents or reducing agents are also used, not only process control but also ~~the~~^a treatment apparatus becomes complicated and, in addition, ~~the~~ cost of treatment increases.

5 To remove CO, it has to be decomposed with oxidizers such as those based on Cu or Mn. As for PFCs, it has been proposed to use alumina as an agent for removing them (Japanese Patent Public Disclosure No. 286434/1998), and this method is characterized by contacting C₂F₆ with
10 molecular oxygen. However, ~~the~~^{an} lifetime of alumina is very short and ~~the~~ throughput or ~~the~~ amount of C₂F₆ that can be treated for 100% decomposition is only 4.8 L/L, ~~what is~~^{Additionally,} ~~more,~~ no effective way has been proposed to deal with CO that occurs as a by-product of C₂F₆ decomposition, ~~still~~^{and}
15 ~~less for the~~ oxidizing gases and acidic gases that occur concomitantly with PFCs.

SUMMARY OF THE INVENTION

The present invention has been accomplished under these circumstances and has as an object providing a method
20 for treating waste gases containing fluorine-containing compounds, which ~~achieves~~^{method} high percent decomposition of PFCs, ~~which~~^{The method to be} proves effective for a prolonged time and ~~which~~ simultaneously realizes effective removal of oxidizing gases, acidic gases and CO that are contained in the waste
25 gases.

Another object of the invention is to provide an apparatus for implementing this method.

~~The~~^A first object of the invention can be attained by a method for treatment of a waste gas containing fluorine-
30 containing compounds, which ~~comprises the steps of~~^{method} separating ~~the~~ solids from the waste gas; adding H₂ and/or H₂O, or H₂ and/or H₂O and O₂, as a decomposition assist gas; thermally decomposing the waste gas by contact with γ -alumina ~~at~~
usually at 500 - 1000°C, preferably ~~at~~^{at} 600 - 900°C, ~~and~~^{and} more
35 preferably ~~at~~^{at} 700 - 900°C, and removing acidic gases from the decomposed waste gas.

In this method, the waste gas containing fluorine-containing compounds may be a waste gas from a semiconductor

fabrication process that contains not only perfluorocarbons and fluorinated hydrocarbons but also oxidizing gases, acidic gases and CO.

^A The second object of the invention can be attained
5 by an apparatus for treatment of a waste gas containing
fluorine-containing compounds, which ^{apparatus} comprises a solids
treating ^{device} means for separating ~~the~~ solids from a waste gas
containing fluorine-containing compounds; an addition ^{device} means
for adding H₂ and/or H₂O, or H₂ and/or H₂O and O₂, as a
10 decomposition assist gas to the waste gas leaving the solids
treating ^{device} means; a thermal ^{decomposition device} decomposing means that is packed
with γ-alumina heated at 600 - 900°C, and which thermally
decomposes the waste gas to which the decomposition assist
gas has been added; an acidic gas treating ^{device} means for
15 removing acidic gases from the thermally decomposed waste
gas; and channels ^{or lines} for connecting these ^{devices} means in sequence.

In this treatment apparatus, a water scrubber may be
used as the solids treating ^{device} means or the acidic gas
treating ^{device} means. This treatment apparatus may have not only
20 an air ejector capable of adjusting ~~the~~ pressure in the
apparatus through which the waste gas passes, but also an
FT-IR analyzer for controlling ~~the~~ emission density of ~~the~~
treated gas.

^A The first step in the method of the invention for
25 treating a waste gas containing fluorine-containing
compounds is passing the waste gas through a solids
treating ^{device} means such as a water scrubber. The ~~Exit~~ gas is
passed through a thermal ^{decomposition device} decomposing means packed with
γ-alumina heated at 500 - 1000°C, preferably 600 - 900°C, and
30 more preferably 700 - 900°C, with H₂ and/or H₂O, or H₂ and/or
H₂O and O₂, being added as a decomposition assist gas, so
that PFCs, oxidizing gases and CO are completely decomposed
into acidic gases and CO₂. The ~~Generated~~ acidic gases are
removed with an acidic gas treating ^{device} means such as a water
35 scrubber.

^{method} The ~~invention~~ may ^{also employ} incorporate not only an air ejector
capable of adjusting ~~the~~ pressure in the apparatus through
which the waste gas passes, but also an FT-IR analyzer for

controlling the emission density of the treated gas.

BRIEF DESCRIPTION OF THE DRAWING

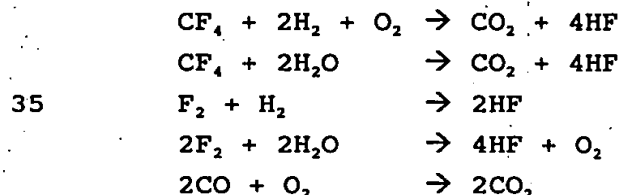
Fig. 1 is a flowsheet ^{chart} for the waste gas treatment apparatus of the invention.

5 DETAILED DESCRIPTION OF THE INVENTION

The present invention is described below in detail.

In the first step, a waste gas containing PFCs, oxidizing gases, acidic gases and CO is passed through a solids treating ^{device} means such as a water scrubber in order to remove not only the solids such as SiO₂ in the waste gas but also Si compounds such as SiF₄, SiCl₄ and SiBr₄ that may potentially solidify in the thermal ^{decomposition device} means at the next stage. If the waste gas is directly introduced into the thermal ^{decomposition device} means without being passed through the solids treating ^{device} means, clogging or other blocking problems will occur, ^{thereby} potentially preventing the waste gas from smoothly flowing through the packed γ-alumina layer. The performance of γ-alumina may also deteriorate. By passing the waste gas through the solids treating ^{device} means, the solids and the acidic gases containing Si compounds are removed, whereas part of oxidizing gases such as F₂, Cl₂ and Br₂, as well as all volumes of PFCs and CO are discharged.

The waste gas emerging from the solids treating ^{device} means is then introduced into the thermal ^{decomposition device} means so that ^{the waste gas} it is decomposed through contact with γ-alumina heated at 500 - 1000°C, preferably 600 - 900°C, more preferably 700 - 900°C. On this occasion, H₂ and/or H₂O; or H₂ and/or H₂O and O₂ are added to the waste gas as a decomposition assist gas so that the components of the waste gas are decomposed into acidic gases and CO₂ according to the following reaction schemes:



Thus, PFC reacts with H_2 and O_2 or H_2O to be decomposed into CO_2 and HF . Acidic gases such as F_2 react with H_2 or H_2O to be decomposed to another acidic gas HF . Carbon monoxide (CO) is oxidized to CO_2 .

5 As for PFC, H_2 or H_2O is added in moles at least equal to the moles necessary for the F atoms in the PFC to be converted ^{into} ~~to~~ HF , and O_2 is added in moles at least equal to the moles necessary for the C atoms in the PFC to be converted ^{into} ~~to~~ CO_2 . Preferably, O_2 is added in moles which
10 are at least equal to the sum of one mole and the above-defined minimum number of moles. As for oxidizing gases, H_2 is introduced in moles at least equal to the moles necessary for the halogen atoms (X) in the ^{on} oxidizing gas to be converted ^{into} ~~to~~ an acidic gas (HX).

15 The waste gas leaving the thermal ^{decomposition} ~~decomposing~~ ^{device} means only contains the acidic gases (HX) and CO_2 , and by subsequent treatment with an acidic gas treating ^{device} ~~means~~ such as a water scrubber, ^{these} the acidic gases are completely removed.

20 The ~~Alumina~~ ^{Alumina} to be used in the invention may have a γ -crystalline structure without a uniform pore distribution. While the shape of the alumina is not limited in any particular way, spheres are easy to handle and, hence, preferred. To the extent that will not unduly increase the
25 resistance to the passage of the waste gas, the particle size of γ -alumina should be as small as possible, preferably between 0.8 mm and 2.6 mm. The γ -alumina may be held at between $500^\circ C$ and $1000^\circ C$, preferably $600^\circ C$ and $900^\circ C$ and more preferably $700^\circ C$ and $900^\circ C$ during the passage of the waste
30 gas.

The solids treating ^{device} ~~means~~ and the acidic gas treating ^{device} ~~means~~ are preferably a packed column or a spray column, on the condition that they are adapted to spray water. The thermal ^{decomposition} ~~decomposing~~ ^{device} ~~means~~ should be adapted to permit the
35 introduction of H_2 and/or H_2O , or H_2 and/or H_2O and O_2 , as a decomposition assist gas.

Fig. 1 is a flow ^{chart} ~~sheet~~ for the waste gas treatment apparatus of the invention. ^{The apparatus} ~~It~~ generally comprises the ^a ~~a~~

solids treating means 1, the ^{decomposition device} ~~γ~~-alumina packed layer 2, the ^{decomposition device} thermal decomposing means 3, a cleaning water circulating pump 4, the acidic gas treating means 5, ^{device} ~~an FT-IR analyzer~~ ^{a Fourier Transform Infrared Spectroscopy} 6, an air ejector 7 and a bypass valve 8.

(hereinafter referred to as an FT-IR analyzer)

5 A waste gas 9 containing PFCs, oxidizing gases, acidic gases and CO is first passed through the spray column (solids treating means 1) so as to remove the solids and Si compounds. The waste gas is then passed through the thermal ^{decomposition device} decomposing means 3, which is also supplied with H₂,
10 O₂ and H₂O to decompose the PFCs, oxidizing gases and CO into acidic gases and CO. The acidic gases are removed by passage through the ^{a subsequent device} next spray column (acidic gas treating means 5), from which the treated gas 10 emerges.

The air ejector 7 is installed to control the pressure in each of the treating means ^{devices 1, 3 and 5} and the FT-IR analyzer 6 is provided to monitor the treated gas.

Spray water 11 is introduced into the acidic gas treating means 5, and the spent water is forced to the solids treating means 1 ^{via} with the cleaning water circulating pump 4. ^{this} the water is used in spraying there and discharged as wastewater 12. ^{is then}

The following examples are provided for the purpose of further illustrating the present invention but are in no way to be taken as limiting.

25 Example 1
An experiment was conducted using a quartz column of 25 mm ^{which} was packed with γ-alumina to a height of 100 mm. The γ-alumina was a commercial product of Mizusawa Kagaku K.K. (NEOBEAD GB-08) having a particle size of 0.8 mm. The quartz column was installed in a ceramic electric furnace and the ^{γ-}alumina layer was heated at 800°C.

In addition to CF₄, diluted with N₂ gas, H₂ and O₂ were supplied as decomposition assist gases, ^{with} the amount of H₂ being such that the number of H atoms was at least equal to the number of F atoms in CF₄, and the amount of O₂ being at least equimolar to the amount of H₂ ^{supplied} introduced. These gases were flowed into the column at a total rate of 408 sccm and their entrance concentrations were ^{1.0} 1% (CF₄), 3.0%

(H₂) and 5.7% (O₂).

In order to evaluate the performance of the treatment system, the exit gas was analyzed periodically and the passage of the CF₄ gas was stopped when the removal of CF₄ dropped below 98%. The throughput was determined from the amount of CF₄ that had been passed through the system. The analysis of CF₄ and other gases was conducted with a gas chromatographic apparatus equipped with a mass detector.

As it turned out, the removal of CF₄ dropped to 98% when its passage continued for 920 min. At this point in time, the throughput as determined from the quantity of the supplied CF₄ was 77 L/L. Throughout the experiment, the concentration of CO emission was below the tolerable level (25 ppm).

15 Comparative Example 1

An experiment was conducted using the same equipment as in Example 1, which was packed with the same γ -alumina in the same amount and heated to the same temperature as that of Example 1. The total gas flow rate was 408 sccm; the feed gas was a mixture of N₂-diluted CF₄ and SiF₄; in addition, H₂ and O₂ were supplied as decomposition assist gases, with the amount of H₂ being such that the number of H atoms was at least equal to the total number of F atoms in CF₄ and SiF₄, and the amount of O₂ being at least equimolar to the amount of H₂ introduced. These gases were flowed into the column at respective concentrations of 0.95% (CF₄), 0.97% (SiF₄), 5.3% (H₂) and 6.0% (O₂).

As it turned out, the removal of CF₄ dropped below 98% when the passage of the CF₄/SiF₄ gas continued for 510 minutes. At this point in time, the throughput was 40 L/L, which was nearly one half the throughput for the case where only CF₄ gas was supplied. Throughout the experiment, the concentration of CO was below the tolerable level.

Example 2

35 An experiment was conducted using the same equipment as in Example 1, which was packed with the same γ -alumina in the same amount and heated to the same temperature as that of Example 1. The total gas flow rate was 408 sccm; the feed gas was a

mixture of N₂-diluted CF₄ and F₂; in addition, H₂ and O₂ were supplied as decomposition assist gases, ^{with} the amount of H₂ being such that the number of H atoms was at least equal to the total number of F atoms in CF₄ and F₂, and the amount of O₂ being at least equimolar to the amount of H₂ ^{supplied} introduced. These gases were flowed into the column at respective concentrations of 0.92% (CF₄), 1.1% (F₂), 5.0% (H₂) and 6.0% (O₂).

As it turned out, ~~the~~ removal of CF₄ dropped below 98% when ~~the~~ passage of the CF₄/F₂ gas continued for 25 hours. At this point in time, ~~the~~ throughput was 115 L/L, which was 1.51 times higher than the throughput for the case where only CF₄ gas was supplied. Throughout the experiment, ~~the~~ concentrations of CO and F₂ were below the tolerable levels (1 ppm for F₂), provided that F₂ had been decomposed into HF.

Reference Example 1

An experiment was conducted using the same equipment as in Example 1, ^{which} that was packed with the same γ -alumina in the same amount and heated to the same temperature. ^{as that of Example 1} The Total gas flow rate was 408 sccm. In addition to N₂-diluted CO, O₂ was supplied in moles at least equal to the moles necessary for CO to be converted ^{into} to CO₂, ^{and} their respective entrance concentrations were 1.4% (CO) and 5.7% (O₂).

Throughout ^a the passage of the feed gas for 30 minutes, ^a the concentration of CO was below the detection limit (2 ppm), ^{into} and all of CO had been oxidized to CO₂.

Comparative Example 2

An experiment was conducted using the same equipment as in Example 1, ^{which} that was packed with the same γ -alumina in the same amount and heated to the same temperature. ^{as that of Example 1} The Total gas flow rate was 408 sccm. In addition to N₂-diluted CO, H₂O was supplied at a rate of 0.090 mL/min, which was 22 times as much as CO, ^{and an} the entrance concentration of CO was 1.3%.

As it turned out, 1000 ppm of CO leaked as a result of ^a 15-minute ^a passage of the feed gas. Obviously, ^a the concentration of CO could not be reduced to below the

tolerable level (25 ppm) by the sole addition of H₂O.

Reference Example 2

An experiment was conducted using the same equipment as in Example 1 ^{which} that was packed with the same γ -alumina in the same amount and heated to the same temperature. ^{as that of Example 1} The Total gas flow rate was 408 sccm. In addition to N₂-diluted CO, H₂O was supplied at a rate of 0.090 mL/min, which was 18 times as much as CO, and O₂ was supplied in moles at least equal to the moles necessary for CO to be converted ^{into} to CO₂.
the Entrance concentrations of CO and O₂ were 1.5% and 3.4%, respectively.

As it turned out, the concentration of CO had been reduced to below the detection limit (2 ppm) after the passage of the feed gas for 3 hours. Obviously, CO was oxidized to CO₂ by addition of O₂.

Example 3

An experiment was conducted using the same equipment as in Example 1 ^{which} that was packed with the same γ -alumina in the same amount and heated to 700°C. ^{as that of Example 1} The Total gas flow rate was 408 sccm. In addition to N₂-diluted CF₄, H₂O was supplied at a rate of 0.040 mL/min, which was 14 times as much as CF₄, and O₂ was supplied in moles at least equal to the moles necessary for the C atom in CF₄ to be converted ^{into} to CO₂. the Entrance concentrations of CF₄ and O₂ were 0.89% and 3.0%, respectively.

As it turned out, the removal of CF₄ dropped below 98% when the passage of the feed gas continued for 23 hours. At this point in time, the throughput was 110 L/L, which was 1.4 times higher than the throughput of CF₄ treatment in the presence of added H₂ and O₂. Throughout the experiment, the concentration of CO was below the tolerable level.

Comparative Example 3

In order to evaluate the effectiveness of the wet process in treating oxidizing gases and acidic gases, a water cleaning column (210 mm^φ x 430 mm^H with a Raschig ring packed to a height of 170 mm) was supplied with a waste gas at a total rate of 60 L/min, and ^{with} spray water at a

rate of 3.5 L/min. The waste gas was prepared from F_2 , SiF_4 , and Cl_2 , which had entrance concentrations of 1100 ppm, 1600 ppm and 5100 ppm, respectively. At the exit of the column, F_2 , SiF_4 , and Cl_2 were detected at concentrations of 11 ppm, < 1 ppm, and 3300 ppm, respectively. Obviously, SiF_4 was effectively treated but F_2 and Cl_2 leaked out.

Example 4

A water cleaning column (210 mm ϕ x 430 mm h with a Raschig ring packed to a height of 170 mm) was used as a solids treating means. This column was combined with a thermal decomposition device comprising a preheating chamber and a catalyst packed chamber, and an acidic gas treating means which was the same as the water cleaning column. The exit gas leaving the acidic gas treating means was monitored with an FT-IR analyzer (Infinity 6000 of MATTSON), and the pressure in the experimental system was controlled with an air ejector of Daito Seisakusho K.K. The solids treating means and the acidic gas treating means were supplied with cleaning water at respective flow rates of 2 L/min and 4 L/min. The thermal decomposition device was supplied with air and pure water at respective flow rates of 10 L/min and 2.4 mL/min. The catalyst was 15 L of γ -alumina (NEOBEAD GB-08 of Mizusawa Kagaku K.K.)

A gas dryer (MD-70-72P of PERMAPUR) was installed ahead of the FT-IR analyzer for removing the moisture in the waste gas. Air was supplied into the air ejector at a rate of 30 L/min so that the pressure in the system was kept at a negative value of -0.5 kPa. A waste gas was introduced at a flow rate of 60 L/min, and it was prepared from a N_2 base containing CF_4 , SiF_4 , F_2 and CO at respective concentrations of 0.5%, 0.3%, 0.3% and 0.3%. The waste gas was first passed through the solids treating means, then passed through the thermal decomposition device in the presence of added water and O_2 , with the catalyst bed being heated at 700°C. The waste gas was subsequently passed through the acidic gas treating means, and the treated gas was continuously analyzed by FT-IR. After the passage of the waste gas for 10 hours, CO_2 was detected in an amount

of 6900 ppm, but each of CF_4 , SiF_4 , HF and CO had been treated to below 1 ppm. No F_2 was detected by ion chromatographic analysis.

Example 5

5 A waste gas treatment was conducted with the same experimental setup under the same conditions as in Example 4, except that CF_4 was replaced by C_2F_6 , and that the waste gas was prepared from a N_2 base containing C_2F_6 , SiF_4 , F_2 and CO at respective concentrations of 0.5%, 0.3%, 0.3% and
10 0.3%. The waste gas was passed through the solids treating means, the thermal decomposing means and the acidic gas treating means.

The treated gas emerging from the acidic gas treating means was continuously analyzed by FT-IR. After the
15 passage of the waste gas for 10 hours, CO_2 was detected in an amount of 11000 ppm, but each of C_2F_6 , SiF_4 , HF and CO had been treated to below 1 ppm. No F_2 was detected by ion chromatographic analysis.

20 a According to the invention, harmful waste gases, from the semiconductor fabrication process, that contain PFCs, oxidizing gases, acidic gases and CO, and which are a potential accelerator of global warming, can be treated in such a way that high percent decomposition is maintained for a prolonged time.

~~METHOD AND APPARATUS FOR TREATING A WASTE GAS
CONTAINING FLUORINE-CONTAINING COMPOUNDS~~

ABSTRACT OF THE DISCLOSURE

The improved apparatus for treatment of a waste gas,
5 containing fluorine-containing compounds, comprises a solids
treating means 1 for separating the solids from a waste gas
containing fluorine-containing compounds, an addition means
for adding H₂ and/or H₂O, or H₂ and/or H₂O and O₂, as a
decomposition assist gas to the waste gas leaving the solids
10 treating means, a thermal decomposing means 3 that is packed
with γ-alumina 2 heated at 600 - 900°C, and which thermally
decomposes the waste gas to which the decomposition assist
gas has been added, an acidic gas treating means 5 for removing
acidic gases from the thermally decomposed waste gas, and
15 channels or lines for connecting these devices in sequence. The
apparatus preferably includes an air ejector which is
adjusting its internal pressure of the apparatus.